Revised Negative Momentum Compaction lattice for PS2

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for the CERN PS2 study team

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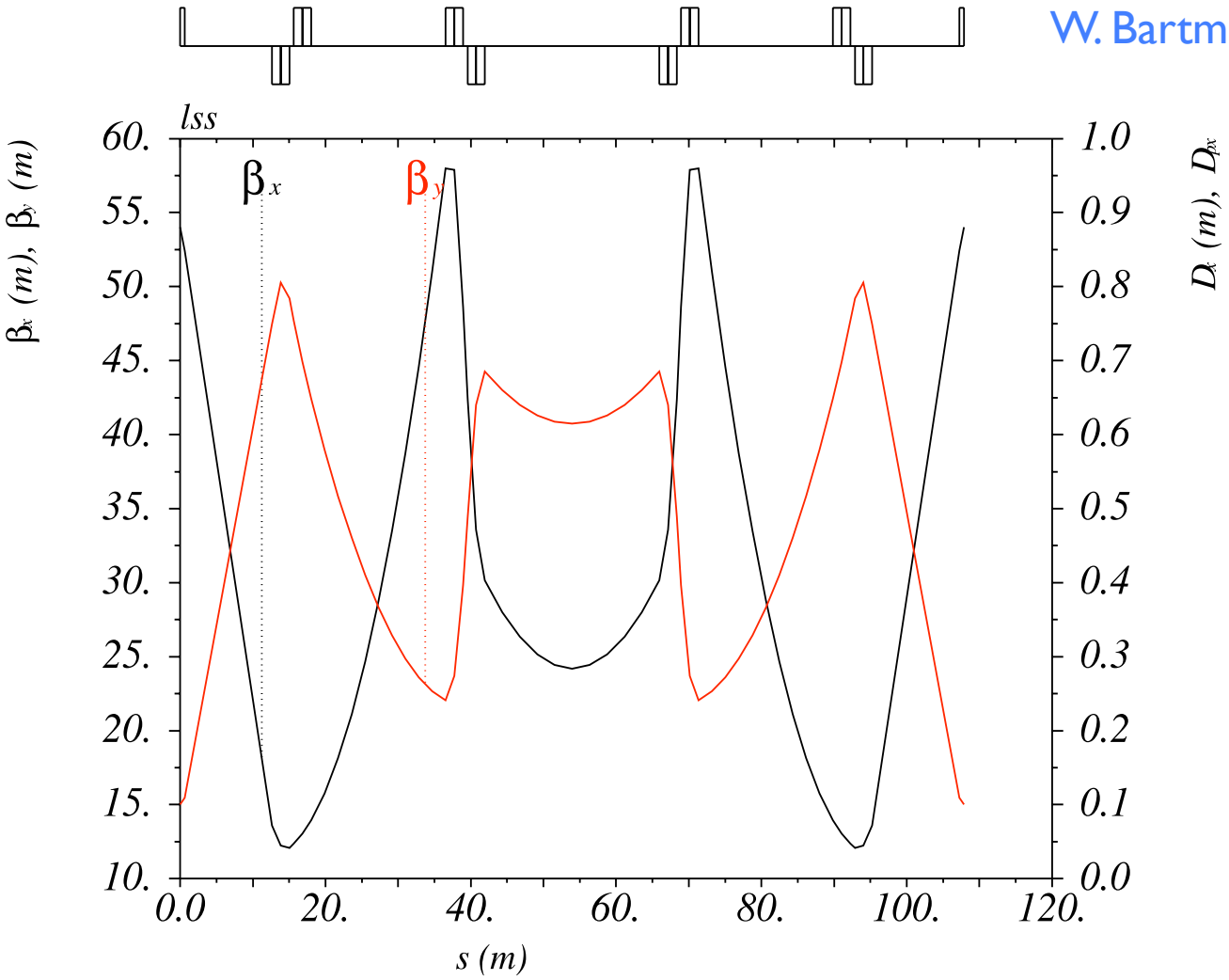
Overview of changes

- Redesign of long straight section (LSS)
  - doublet structure reduced length to 107.9m from147m
- Allows to lengthen dispersion suppressors
  - Length increased 64m to 78.6m (optics becomes smoother)
  - Increased number of dipoles in the suppressor to 10 (instead of 9)
- Imposed stronger optics constraints to gain magnet design margin and space for vacuum and insturmentation
  - Maximal quad. Gradient reduced to 15T/m (17T/m)
  - Minimal drifts between dipoles increased to 0.7m (0.6m)
  - Minimal drifts between quads increased 1.3m (1.2m)
- Reduced types of quadrupole magnets to 4 instead of 5
  - Lengths of 0.8m, 1.6m, 2.2m and 2.4m (wide aperture ones for LSS)

Long straight section



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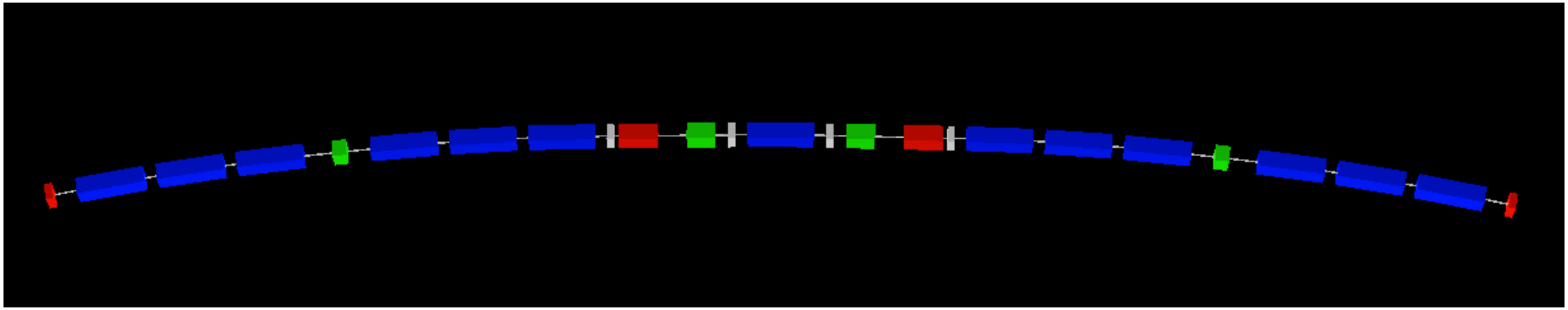
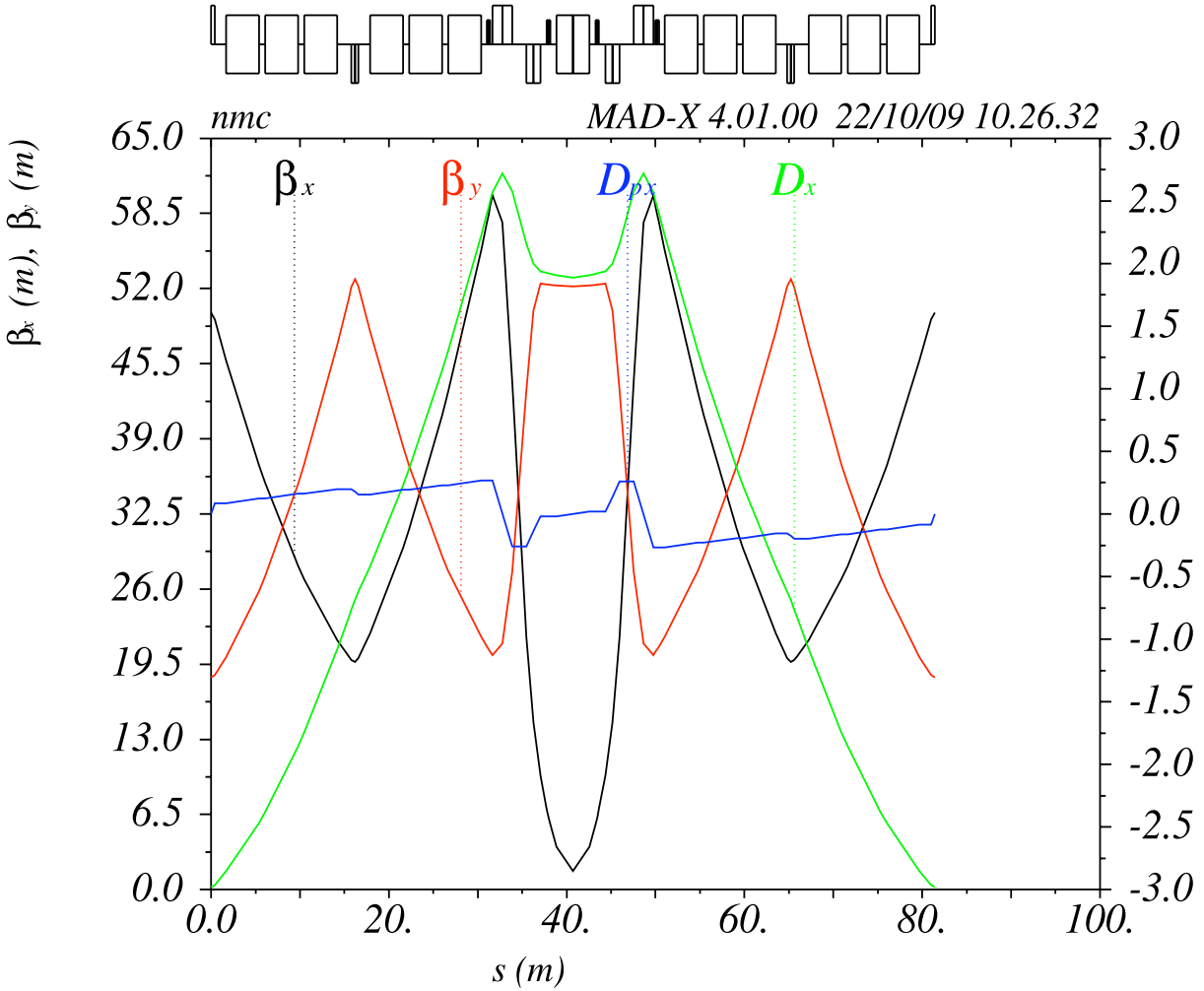
- LSS with phase advance of (μ_x, μ_y)=(0.7, 0.55)
- Quadrupole lengths not yet homogenized
- Quadrupoles can be shortened to match arc length types but some require wider apertures.

NMC Cell layout



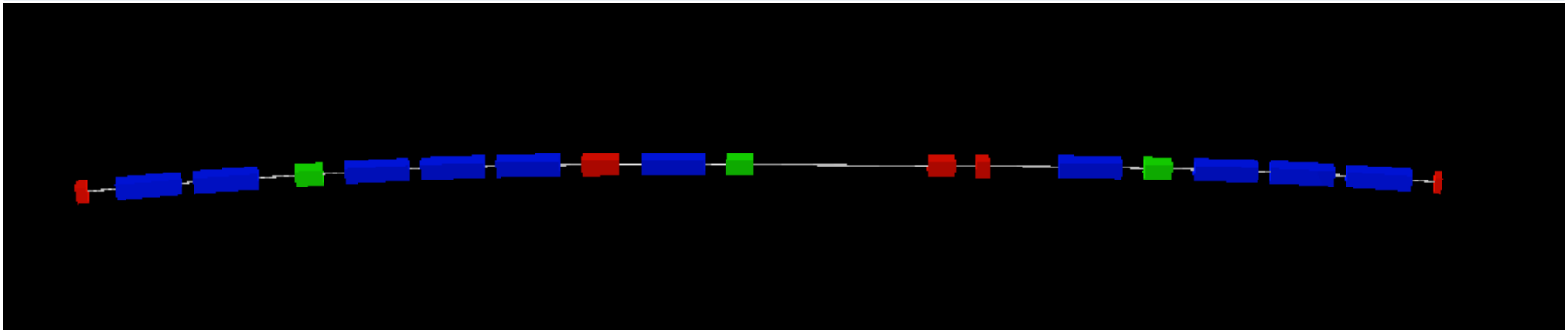
Element	Type	Length [m]	occurrences
PS2.MQA.MOD.1	F. Quad	0.8	½ + ½
PS2.MQA.MOD.2	D. Quad	0.8	2
PS2.MQB.MOD.3	F. Quad	2.2	2
PS2.MQC.MOD.4	D. Quad	1.6	2
MB	Dipole	3.69	13
PS2.MS.2	Sextupole	0.4	2
PS2.MS.3	Sextupole	0.4	2

NMC Cell optics



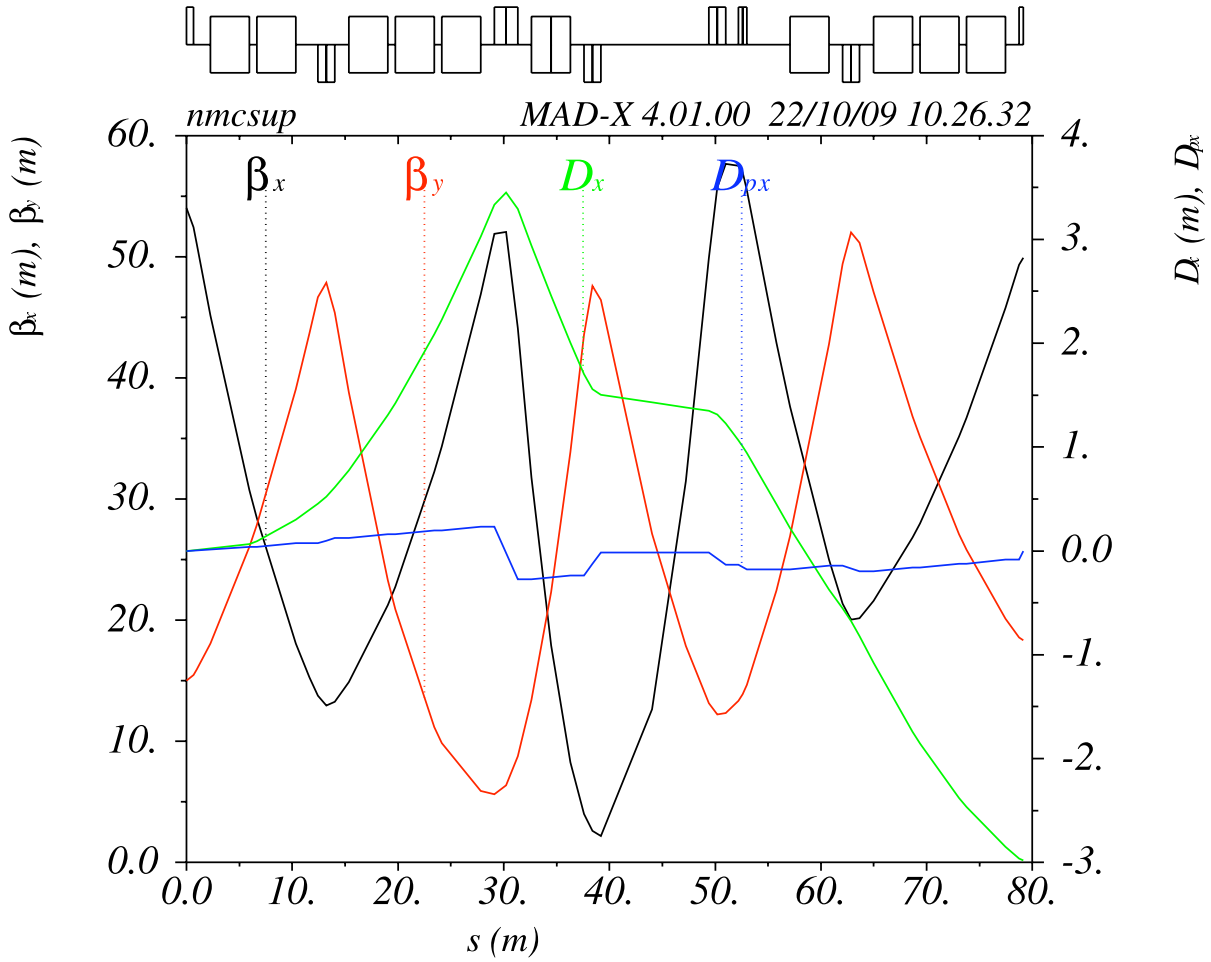
- Adapted NMC cell to new drift space constraints
- Plot shows cell tuned to (0.754, 0.409)
- $\beta_{x\,max}$ = 60.1m
- $\beta_{y\,max}$ = 52.8m
- γ_t = 19.5 i
- This phase advance used for new working point

Suppressor layout



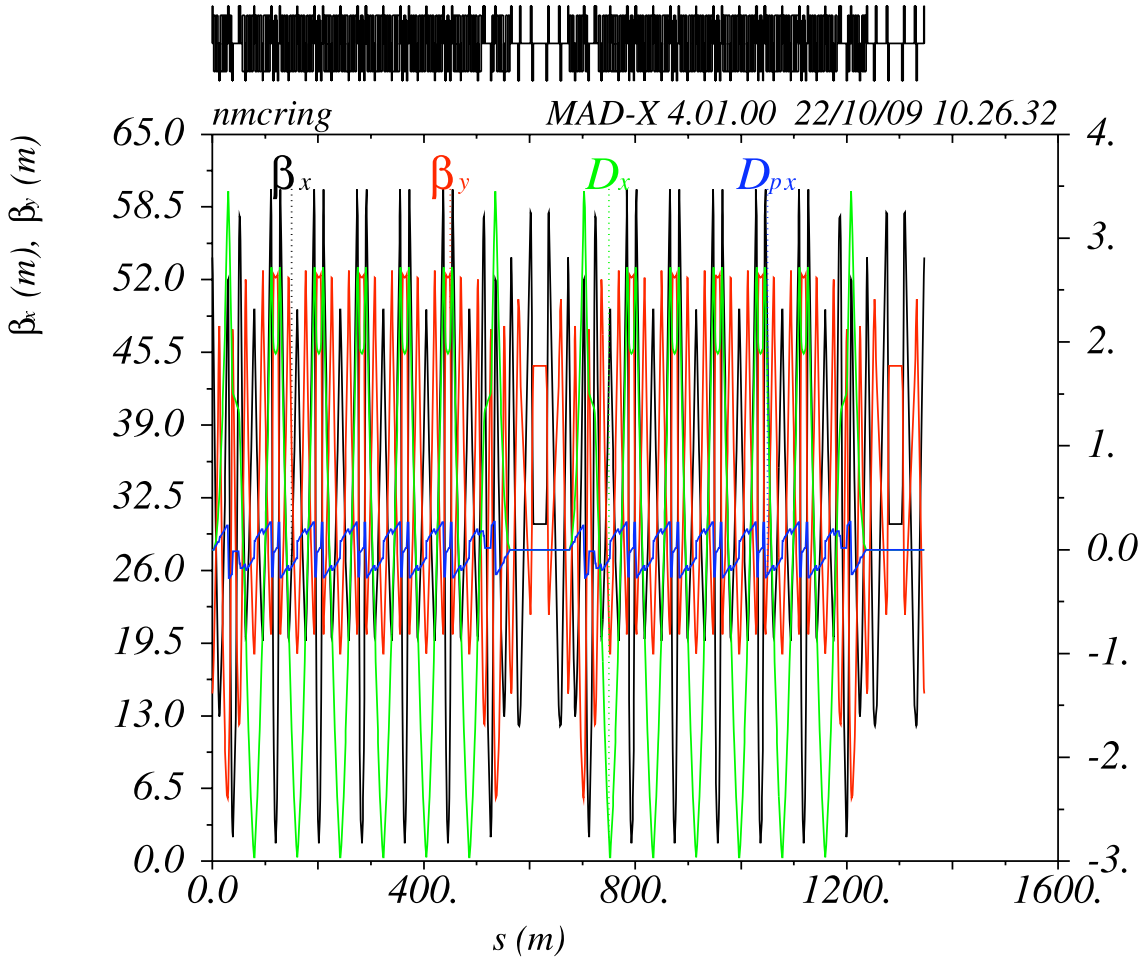
Element	Type	Length [m]	occurrences
PS2.MQC.LSS.1	F. Quad	1.6	1/2
PS2.MQC.SUP.10	D. Quad	1.6	1
PS2.MQB.SUP.9	F. Quad	2.2	1
PS2.MQC.SUP.8	D. Quad	1.6	1
PS2.MQC.SUP.7	F. Quad	1.6	1
PS2.MQA.SUP.6	F. Quad	0.8	1
PS2.MQC.SUP.5	D. Quad	1.6	1
PS2.MQA.MOD.1	F. Quad	0.8	1/2
MB	Dipole	3.69	10

Dispersion Suppressor optics



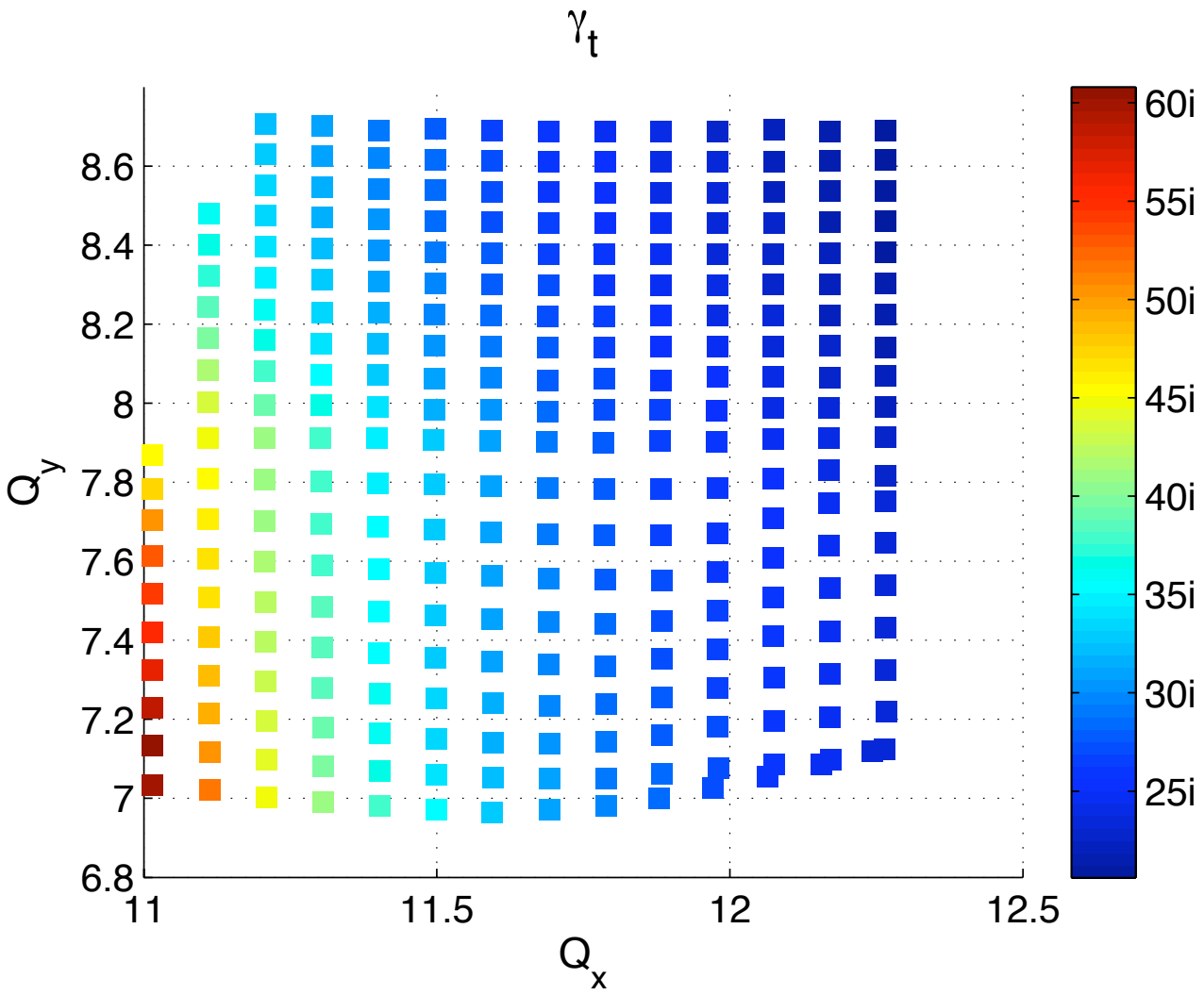
- Increased length to ~80m
- 10 instead of 9 dipoles
- High peak values of horizontal beta function is avoided for a wide range of working points
- No additional type of quadrupole needed (old version needed 4th type)

New working point (11.88, 7.78)



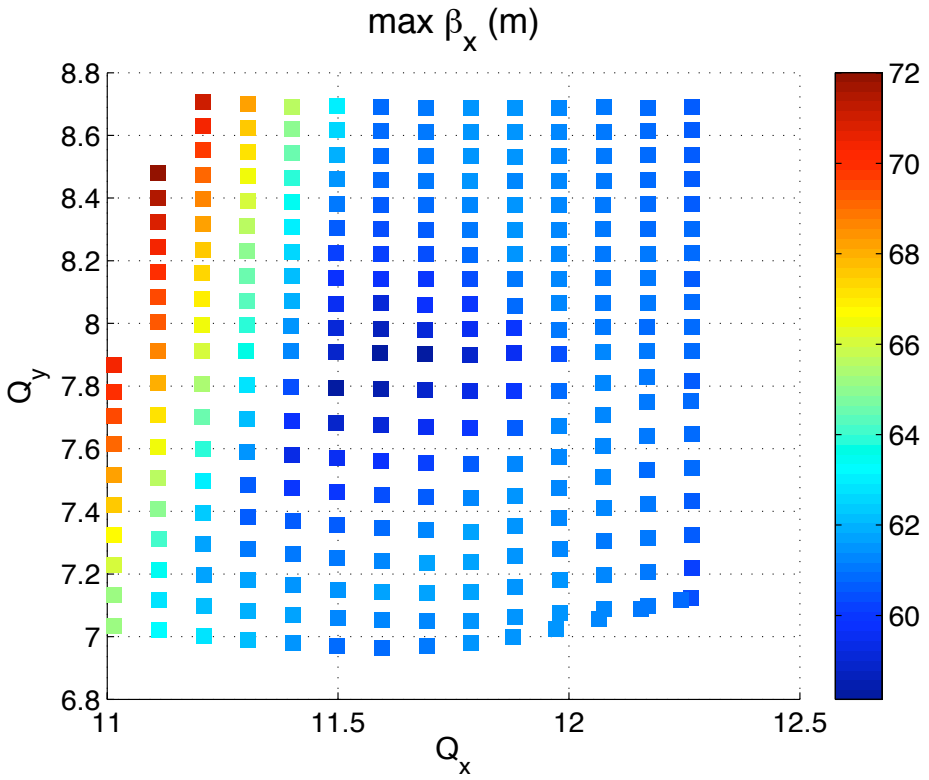
- NMC cell tuned to (0.754, 0.409)
- Ring parameters
  - $\beta_{x,max}$ = 60.1m
  - $\beta_{y,max}$ = 52.8m
  - γ_t = 26.8 i
  - η_{max} = 3.45m
  - ξ_x = -21.7
  - ξ_y = -11.8

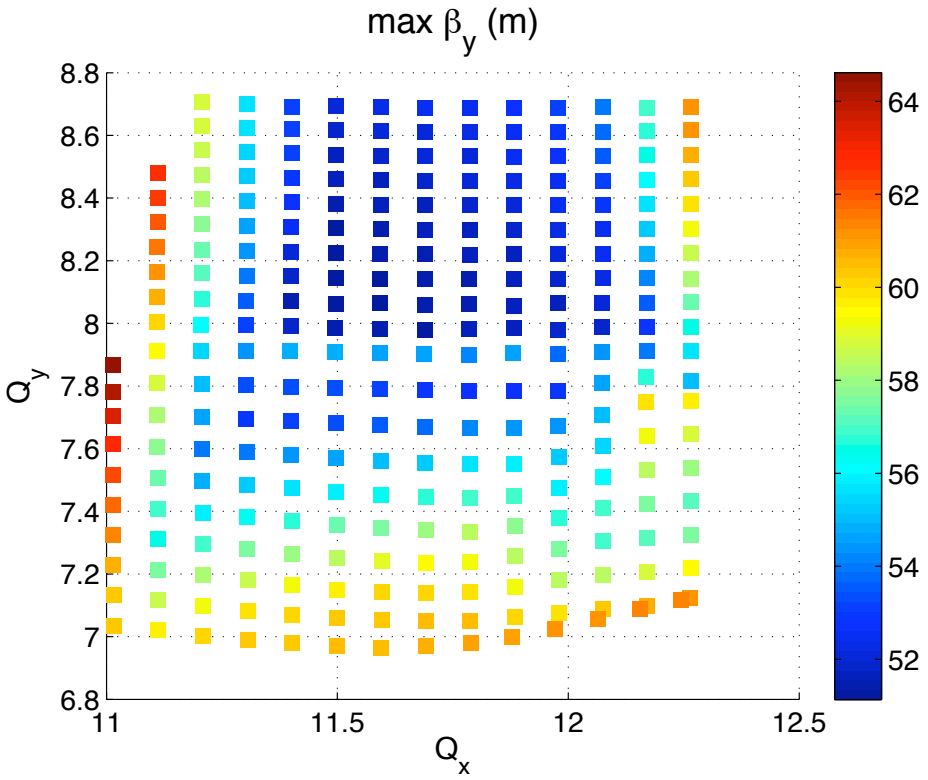
Transition energy, γ_t



- Tuning a large number of working points while having a completely fixed straight section optics
- Transition energy varying from around **20i** to **60i**
- Larger phase advances in the arc cell produce lower transition energies (stronger focusing, larger dispersion excursion) and vice-versa

Maximal β - functions





- Maximal β_x located in NMC cell
- Around 60m for most working points

- Maximal β_y mostly in Suppressor
- Below 60m for most working points

Tunability – Overview (1)

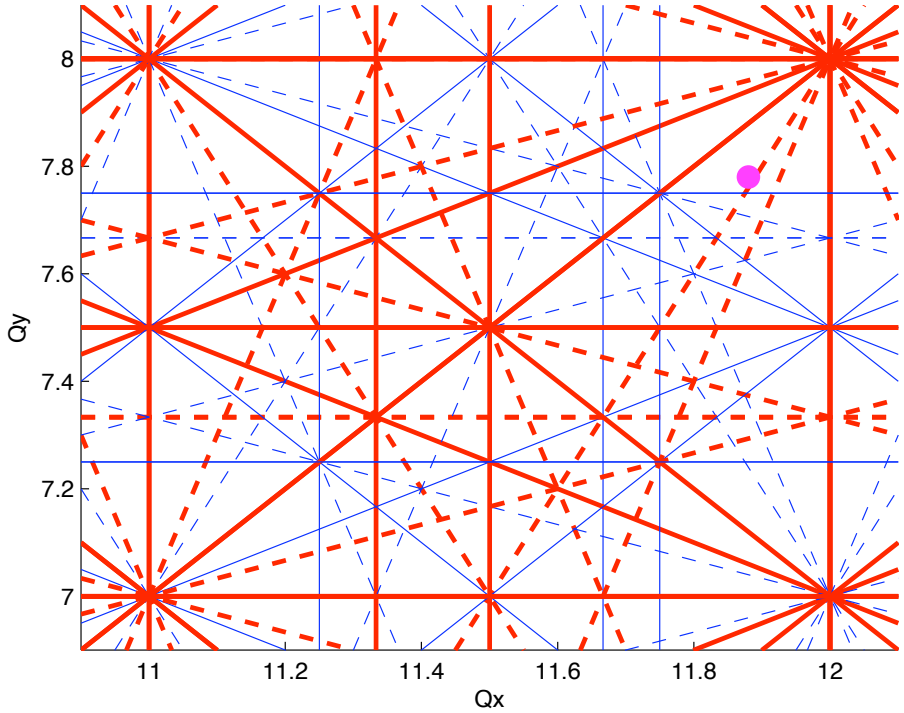
Parameter	Min value	Max value	Comment
$\mu_{x,NMC}$	0.682	0.786	
$\mu_{y,NMC}$	0.345	0.521	
$Q_{x,Ring}$	11	12.5	
$Q_{y,Ring}$	7	8.7	
$\beta_{x,max}$ [m]	58	72	In NMC cell
$\beta_{y,max}$ [m]	51	65	In η -suppressor
γ_t	20i	60i	
η_{max} [m]	3.4	3.75	In η -suppressor
ξ_x	-20.8	-22.6	
ξ_y	-11.2	-12.6	

Tunability – Overview (2)

Magnet	Min gradient [T/m]	Max gradient [T/m]
PS2.MQA.MOD.1	10.54	13.77
PS2.MQA.MOD.2	11.56	14.96
PS2.MQB.MOD.3	14.62	15.64
PS2.MQC.MOD.4	12.155	13.175
PS2.MQC.SUP.5	7.65	9.18
PS2.MQA.SUP.6	1.7	14.45
PS2.MQC.SUP.7	5.95	13.6
PS2.MQC.SUP.8	14.195	15.05
PS2.MQB.SUP.9	11.288	11.509
PS2.MQC.SUP.10	10.2	11.39

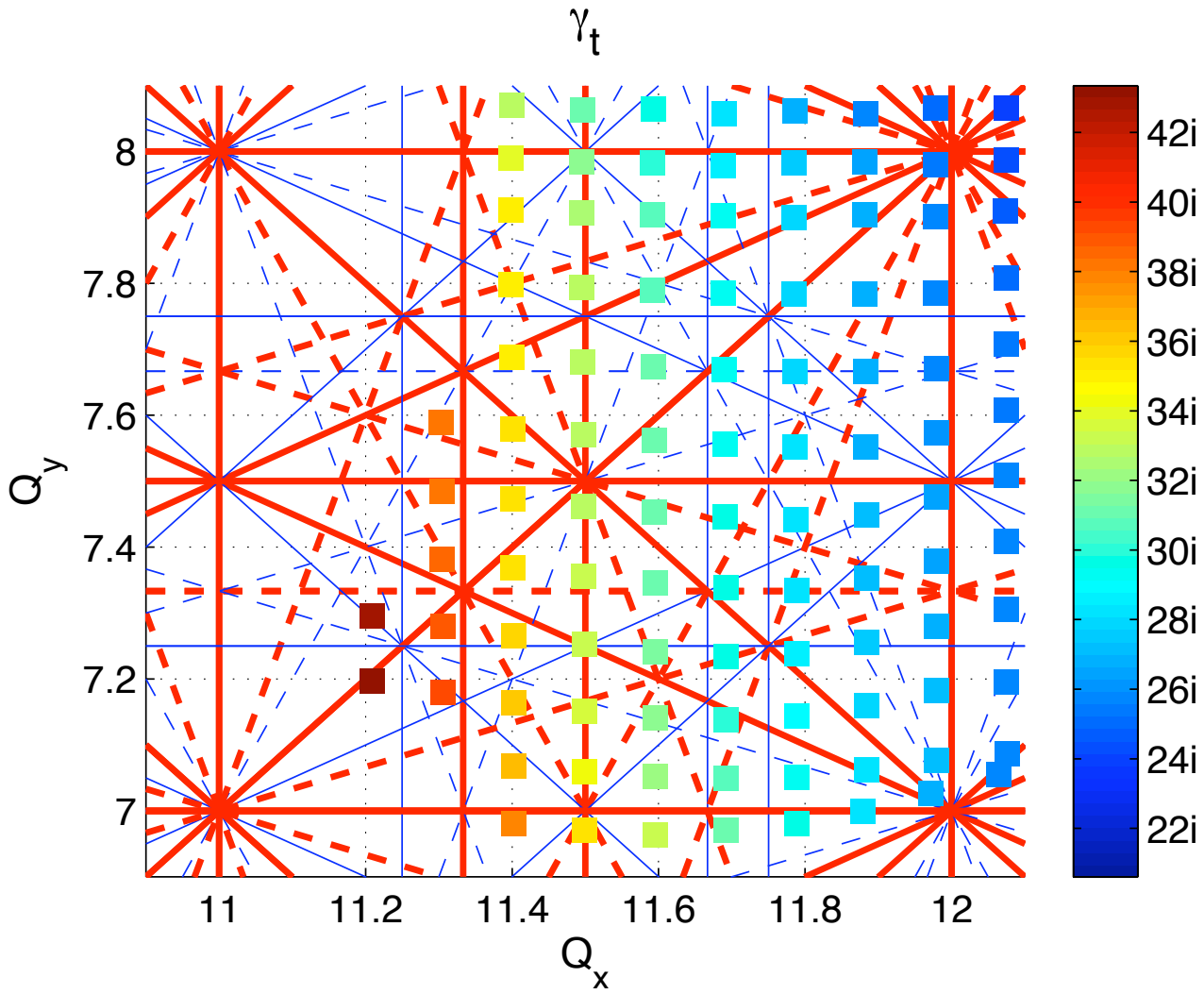
Change of tunes

- New LSS has lower phase advance in both planes
  - Potential working point in the range of (μ_x, μ_y): 11-12, 7-8
- Working point near (Q_x,Q_y): 11.85, 7.8 seems interesting



- Tune diagram shows resonances up to 4th order
- red=systematic, blue=random
- solid=normal, dashed=skew
- Pink star represents the working point (Q_x,Q_y): 11.88, 7.78

Good region of tune diagram



- Plot shows all working points with max β_x = 62m and max β_y = 62m
- Further optimization may allow to reduce the max. β functions below 60m

Summary - conclusion

- New refined PS2 optics are more comfortable with respect to magnet strength space and tunability
- Reduced number of quadrupole types
- No changes on aperture requirements
- New tune range between (11-12,7-8)
  - Horizontal tunes between 11 and 11.3 hard to reach (max β_x up to 70m)
- Further optimization may allow to *slightly* reduce max β functions
- Work on-going on all resonant 3-periodic ring (Y. Senichev)
  - Difficult to keep space constraints
- Chromaticity correction has been done and non-linear analysis is on-going

Rough Planning

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- After a first non-linear dynamics optimization, evaluate best working point (until end 2009)
- Freeze the nominal lattice within the next 3 months (including apertures)
  - Refine main magnet and start vacuum systems design (dimensioning)
- Progress in parallel with the study of a 3-periodic lattice (resonant or not)
- Organize an external review on the lattice (Spring 2010 ?)
- Continue with study of correction systems (linear and non-linear) (2010)
- Proceed in non-linear dynamics analysis including space charge (2010)
- Start detailed study of collective effects (2010-2011)
  - Impedances, instabilities, e-cloud,…
- Refine collimation system design (2010)
  - Adapt it in new LSS and start FLUKA simulations
- Collect all relevant information for Conceptual Design Report (mid 2012)